An Open Platform for Building Information Modeling (BIM) Education: Conceptual Framework and Potential Impact

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Abstract

The AECO industry urgently needs to enhance its workforce skills and undergo digital transformation to boost productivity, sustainability, and climate protection. A significant barrier is the shortage of specialists proficient in digital methods like BIM. This paper explores the disconnect between current educational programs and the industry's needs, discussing the difficulties in updating curriculums, integrating digital training, resistance to change within educational institutions, and unequal access to digital resources. We propose a community-driven open platform for BIM education, utilizing open standards and interoperable data formats to facilitate easy access and practical engagement for educators, students, and professionals. Our framework advocates for cooperation among industry, academia, and policymakers to create adaptive curriculums and invest in digital infrastructure and educator training. This platform aims to democratize education in digital construction, promoting equitable learning opportunities and fostering the industry's digital advancement through cost-effective, early, and interdisciplinary training.

1. Introduction

The construction industry faces significant challenges in the coming years, including a severe shortage of skilled workers and the need for digital transformation to achieve sustainability and climate protection goals. The industry must adapt to technological change and implement digital working methods, such as Building Information Modeling (BIM), to meet these challenges (Beetz et al., 2018; Eastman et al., 2018). However, the lack of qualified professionals with digital knowledge and experience significantly limits the implementation of digitalization initiatives. There is an urgent need to strengthen

education and training in universities, educational institutions, companies, and public institutions (pwc GmbH, 2023).
To address these challenges effectively, the education sector must overcome several key pain points (Brandenburger et al., 2021; McCarthy et al., 2023): Firstly, there is a significant gap between the digital skills currently taught in educational institutions and the evolving needs of industries like construction. This discrepancy leads to a workforce inadequately prepared for the digital demands of modern job roles. Secondly, there is an urgent need for curriculum updates and the integration of hands-on, practical digital training, which is often lacking in traditional educational settings. This includes theoretical knowledge and applying digital tools and methodologies specific to construction-related industries. Furthermore, there is resistance to change within the education system, which can slow the adoption of new technologies and teaching methods. Educators need upskilling and continuous professional development to stay abreast of digital trends and tools. Additionally, access to cutting-edge digital resources and infrastructure is uneven, creating disparities in learning opportunities, especially in underprivileged or remote areas. To overcome these challenges, a collaborative effort is needed. Industry leaders, educational institutions, and policymakers must work together to develop curriculums responsive to the digital age's needs. Investments in digital infrastructure and teacher training are crucial, as is creating more experiential learning opportunities, such as internships and project-based learning, directly aligned with industry requirements.

2. State of the Art - Literature Review

The education of students and professionals is a critical success criterion for successfully implementing the BIM method. Due to the changes in the AECO industry concerning sustainability, digitalization, and shortage of skilled workers, students must be taught BIM as a basis for shaping change, taking into account the aspects (1) Data, (2) Context, (3) Technology, (4) Processes and (5) Actors (Halter, 2022; Wimmer et al., 2023). This enables students to react better to the changes, as well as to their professional profiles. Studies from other disciplines have shown that teaching must go beyond mere knowledge transfer and enable students to think independently and develop new concepts (OECD, 2018; Orr et al., 2020). Therefore, the current state of the art for BIM education will first be presented and discussed, along with the need for future-orientated education. This section concludes by evaluating the need for further BIM education by considering future student skills.
Teaching the big openBIM method has significant potential for the future transformation of the AECO industry. A wealth of excellent literature describes and regularly updates the essential vendor-neutral tools and working methods for the AECO industry (Domer & Rachele A. Bernardello, 2023; Eichler et al., 2024). Although BIM is generally taught discipline-specific and isolated, there is no coordinated and consistent BIM teaching across the curriculum. This can primarily be evaluated by taking a closer look at the course handbooks of German universities analyzed for this paper. Furthermore, the three following aspects, which are regularly mentioned in research- and teaching projects, characterize the teaching of BIM:

- **Traditional Forms of Teaching:** BIM education often relies on traditional teaching methods in civil engineering, such as lectures and exercises. While there's been an increase in group work and BIM summer schools, traditional exams remain common. However, collaborative learning is recognized as beneficial for enhancing outcomes (Peterson et al., 2011; Tomcho & Foels, 2012).

- **Lack of Model-Centric Teaching:** BIM education lacks a model-centric teaching approach and focus on data exchange, particularly across disciplines and throughout a building's lifecycle (Pieper et al., 2021). At the same time, some courses prioritize open exchange formats (e.g., (Freudenberg et al., 2022)), and most focus on specific authoring tools. Initial evidence suggests that model-centered courses improve understanding and model quality (Brandenburger et al., 2021).
- **BIM is often taught as Software Tool:** BIM education confines BIM to a software tool, neglecting other critical aspects like processes, interdisciplinary interactions, regulations, and standardization alongside computer science principles (Maile et al., 2023).

As shown above, universities must prepare their students for their future jobs and develop innovations. For facing and reacting to global challenges, like complex social challenges and the sustainable and digital transformation of industries - especially the AECO industry - future skills are required, such as analytical, social, and digital skills (OECD, 2018; Wissenschaftsrat, Mai 2022). BIM could be one course and, later in practice, one method that combines these aspects. Therefore, it is necessary to change the way from silo-based thinking to a transdisciplinary, model- and use-case-centric approach for teaching BIM in the AECO industry.

3. Methodology

To effectively address these significant challenges, it is essential to employ various strategies in collaboration. Among these, the sharing and dissemination of knowledge stand out as particularly crucial elements (McCarthy et al., 2023; Peterson et al., 2011). Starting this process as early as possible is vital to facilitating success and overcoming obstacles. This paper proposes an open platform for BIM education, offering access to practical, vendor-neutral use cases. While similar initiatives exist (GIScience - Universität Heidelberg, 2024; WPW LEIPZIG GmbH, 2024), none are tailored to digital methodologies in construction, highlighting a significant gap. The platform aims to bridge this gap and expand digital knowledge across the sector.

An educational platform has the potential to democratize education in a specialized field by making content accessible to a broad audience and adapting it to the evolving needs of learners and industry. Therefore, our proposed concept focuses on using open standards and interoperable data formats (big openBIM) to facilitate the seamless integration of different software and disciplines and thus improve the accessibility of content for different groups (Maile et al., 2023). It is not just about the traditional target groups already being addressed in their environment but also about reaching and integrating sectors that have so far been left behind by digitalization, such as the skilled trades. These groups, who rely on craft skills and techniques passed down from generation to generation, play a central role in the delivery of construction projects but are often excluded from digital advances. By including specific information and training programs for these groups in our open platform, we aim to bridge the digital divide. As part of our proposed initiative, this group will also have the opportunity to receive tailored resources and tools to improve the digital literacy of tradespeople and other professionals who are not from the digital world. The goal is to create a more inclusive digital ecosystem that recognizes and values the unique contributions of all sectors within the industry. Fostering a practical, inclusive, and flexible learning environment bridges the gap between academic learning and professional application.

To further improve the platform's effectiveness and relevance, it will be structured based on use cases, as is already common practice in describing the structure of BIM-based

Figure 1: Positioning of an openBIM education platform with key areas of focus and stakeholders

projects. Across the industry, an understanding has developed that use cases are a reasonable basis for learning from each other, as these individual processes can be built up like puzzle pieces, connected, and shared. This is why standardization efforts are now describing use cases and corresponding recommendations published for this purpose (VDI, 2022). To use these advantages, the platform's structure is envisioned to be use-case-oriented, mirroring the organization of BIM-based projects. This approach enables quick identification and engagement with relevant content, catering to the specific needs and research focuses of educators, students, and professionals.

Moreover, the platform is designed to be community-driven, promoting a collaborative environment for knowledge sharing and continuous development. Members of this community, including educators, students, and industry professionals, can contribute educational materials, practical use cases, and best practices. On the one hand, this approach improves educational outcomes by aligning education with real-world practice and innovation and supports continuous community-driven skill and knowledge development. On the other hand, an active and vibrant community has the potential to ensure that educational content remains relevant and can respond to technological advances and market demands.

To keep the community itself, but especially the educational content, alive, a feedback system will be incorporated, allowing users to rate and review content. This will ensure the quality and relevance of the materials and provide insights into the community's needs, guiding future platform improvements. Figure 1 shows how this platform fits into the environment and the stakeholders.

4. Design, Development, and Deployment of an open BIM Education Platform

The proposed platform's central concepts and components are based on existing technology, such as source code repositories and BIM use case definitions. Modern collaborative software development is based on source code repositories such as *git* that enable open and community-driven development. Since the proposed platform goals strongly align with those of open-source code repositories, incorporating such a repository is an evident choice.

4.1. Platform Design and Structure

In Figure 2, the platform is depicted as consisting of three primary layers:

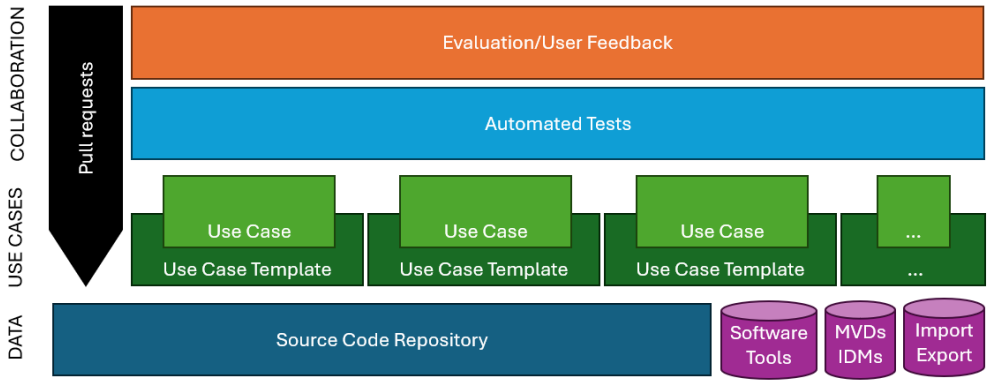

Figure 2: Main structure of the platform

- **Data Layer:** The data layer manages all underlying data, including a robust database and a source code repository. The database catalogs tools, interoperability standards (like IFC, BCF, IDMs, MVDS, and various import and export versions), and metadata for version control of tools and documents. Integrating a version control system, such as git, supports collaborative development and maintenance of educational content and code.

- **Use Case Layer:** Above the data layer, the use case layer serves as the platform's functional core. It includes detailed templates for each BIM use case, facilitating standardization and quality assurance. These templates provide a structured approach to educational content, ensuring that all necessary aspects (like LOIN requirements and process descriptions) are consistently addressed. They thus play a crucial role in guaranteeing comparability among use cases and serve as the foundation for quality assurance.

- **Collaboration Layer:** The top layer focuses on user interaction and content evolution. It features tools for community engagement, such as forums and collaborative editing tools. This layer supports real-time updates and feedback, which is essential for maintaining the relevance and accuracy of the content. These collaboration layer functionalities will be integrated via pull requests, allowing for the review of differences and changes and the execution of automated tests before integration (merging) into specific use cases within the use case layer. Pull requests are a mechanism of source code repositories to review proposed changes collectively and attach automated tests to be executed even before changes are integrated.

Having delineated the platform's layered architecture, the technical specifications ensuring its functionality and user-friendliness must also be addressed. These specifications are designed to uphold the platform's commitment to interoperability, data integrity, and security:

- **Interoperability and Open Standards:** Adhering to openBIM standards, the platform ensures that data and content are interoperable across various BIM software. This approach not only enhances accessibility but also fosters a broader adoption by avoiding vendor lock-in.

- **Use Case Orientation:** The platform centers on structured, well-documented use cases, a crucial element for driving digitalization in the building industry. These tem-

plates, including metadata, process diagrams, and technical details, are based on VDI standards (VDI, 2022).

While the technical framework sets the foundation for a robust educational platform, it also presents unique challenges that require careful consideration and proactive management. Potential hurdles demand effective strategies for mitigation, ensuring the platform remains scalable, secure, and engaging for all users:

- **Scalability:** As user numbers grow, maintaining platform performance is crucial. Utilizing cloud services with elastic scalability can address this challenge, ensuring the platform remains responsive as demand increases.
- **Content Quality and Relevance:** Ensuring educational materials' quality and up-to-date nature is challenging, especially in a rapidly evolving field like BIM. To mitigate this, the platform incorporates a peer-review process and a dynamic update mechanism where community members and experts can propose updates through a structured review system.
- **User Engagement:** Engaging a diverse user base can be intricate. The platform includes gamification elements such as badges and leaderboards to enhance user engagement and encourage participation and learning progression.

By focusing on these aspects, the platform aims to provide a robust, scalable, and engaging environment that supports the diverse needs of the BIM education community. This strategic design ensures that the platform serves as a knowledge repository and a living community that evolves with users' needs.

4.2. Content Creation and Maintenance

As mentioned, creating and maintaining dynamic content poses a major challenge in ensuring that the resources provided are up-to-date, relevant, and of high quality. For this reason, the following section presents the main concepts that are implemented by the platform:

- **Community-Driven Content Development:** At the heart of the platform is community-driven content development. It engages various academia, industry, and research experts to contribute to a rich and diverse knowledge base. Members can submit educational material, practical use cases, and best practices based on their experience. This collaborative approach promotes knowledge diversity and enables rapid adaptation to new technologies, methodologies, and standards in the BIM sector (GIScience - Universität Heidelberg, 2024).
- **Editorial Guidelines and Content Curation:** Editorial guidelines are in place to ensure the quality and consistency of content. These guidelines cover accuracy, objectivity, clarity of content, and formatting and structuring requirements. An editorial team of experienced professionals and academics reviews submitted content for compliance with these guidelines. This content curation process ensures that only high-quality and relevant material is published (Coursera Inc., 2024).
- **Updates and Revisions:** BIM technologies and best practices are constantly evolving. Therefore, the content provided on the platform must be regularly reviewed for currency and accuracy and updated or revised as necessary. This ongoing process

supports the platform's long-term relevance and helps users stay informed of developments. In turn, the community actively suggests changes and provides feedback on existing content (GIScience - Universität Heidelberg, 2024).

- **Communication & Openness:** Open communication and transparency are fundamental principles of the platform. A forum or discussion platform facilitates interaction between users, contributors, and the editorial team. This encourages dialogue and exchanging ideas and allows direct communication about questions, suggestions, or problems. Open communication strengthens the community and contributes to the continuous improvement of the platform (WPW LEIPZIG GmbH, 2024).
- **Pull Request Concept:** Adopting a practice widely used in software development, particularly in platforms like *git*, the platform implements the 'pull request' concept to manage content submissions and revisions. Community members can suggest changes or new content by submitting a pull request, which is then reviewed by the editorial team before being integrated into the platform's primary resources. This process encourages community involvement while providing a layer of quality control through editorial review (GIScience - Universität Heidelberg, 2024).

Combining these elements allows the platform to create a sustainable ecosystem for developing, maintaining, and updating BIM-related educational materials and resources. This will promote digital competency in the construction industry and support the sector-wide adoption of BIM technologies and methods.

4.3. Quality Assurance, Feedback, and Evaluation

Developing and maintaining high-quality educational content is crucial to the success of the openBIM education platform, as this is the only way to create the necessary trust in the content so that it is used, shared, and further developed. Thus, we propose a comprehensive quality assessment system to ensure both the relevancy and the quality of the content provided. This system combines automated assessments with community-driven evaluations, allowing for scalable maintenance and deep insight into the content's impact and relevance. In our quality assurance system, we distinguish between two basic types:

- **Automated Quality Assessment Criteria:** Automated assessments allow for scalable, initial quality checks on submissions and updates. These criteria focus on the technical and structural aspects of the content.
- **Community-Driven Evaluation Mechanisms:** Our platform emphasizes community-driven evaluation mechanisms inspired by the open-source software model's reliance on community input. We invite users—educators, students, and industry professionals—to actively participate in content review and curriculum updates. This participatory approach enriches our content and fosters ownership and real-world alignment. Like feedback systems in community health or urban planning, our platform integrates diverse stakeholder perspectives to refine and adapt educational offerings continuously. The insights from our community of educators, students, and professionals are crucial in evaluating content quality and ensuring it meets practical experience and educational needs.

Table 1: Quality Assessment System with Prioritization

Type	Criterion (Description)	Example of Implementation	Ease of Automation	Ease of Implementation	Priority
Automated - Objective assessments	**Comprehensiveness (Coverage of topics)**: evaluates whether the content adequately covers all relevant topics outlined in the educational or professional standards. It ensures that users receive a holistic understanding of the subject matter.	Implement an automated content analysis tool that scans educational materials to verify that all required topics are addressed. This tool could use a checklist of predetermined topics integral to BIM education, marking each as covered or not based on textual or keyword analysis.	●●●●○	●●●○○	⇑
	Language and Clarity (Readability): ensures that the educational content is written in clear, comprehensible language suitable for the target audience, enhancing readability and accessibility.	Use Natural Language Processing (NLP) tools to assess the text's readability score, ensuring it matches the educational level of the target audience. The tool should also check for grammatical accuracy and suggest simplifying complex language.	●●●○○	●●●●○	⇑
	Metadata Quality (Searchability): Focuses on the quality of metadata associated with educational materials, facilitating easier searching and categorizing content within the platform.	Algorithms can automatically check for completeness and accuracy of metadata tags, descriptions, and keywords. This ensures all content is easily searchable and properly indexed, enhancing user experience.	●●●●○	●●●●○	⇑
	Objective Clarity (Goal specificity): Assesses whether the learning objectives of the content are clearly defined, measurable, and aligned with the overall educational goals.	An automated review tool can analyze objective statements within educational materials to ensure they are specific, clear, and measurable. This tool might use AI to suggest modifications to align with best practices in instructional design.	●●●●●	●●●○○	⇑
	Up-to-date Information (Timeliness): Ensures the content remains current and reflects the latest industry standards, technologies, and practices.	Implement a date stamp analysis tool that identifies content older than a specified timeframe (e.g., two years) and flags it for review. This helps maintain the relevance and accuracy of the educational materials.	●●●○○	●●●●○	⇒
	Completeness (Inclusion of learning elements): Verifies that the educational content includes all necessary elements such as learning objectives, key concepts, examples, assessments, and supplementary resources.	Use a checklist-based verification system that scans content to ensure all critical learning elements are present. Each item on the checklist is essential to a complete educational module.	●●●○○	●●●○○	⇒
	Resource Accessibility (Availability of tools/materials): Ensures that all necessary resources, tools, and materials required for practical application are readily available and accessible to users.	Automated verification checks that all links to external tools, downloadable materials, and online resources are functional and accessible. This could include link validation tools and accessibility checks against various user scenarios.	●●○○○	●○○○○	⇒
	Instructional Design Quality (Educational structure): Evaluates the structure and organization of the content to ensure it follows best practices in instructional design, facilitating effective learning.	Structured analysis tool against established instructional design principles to assess content organization, pedagogical flow, and engagement strategies. This tool could provide feedback on structuring content more effectively to enhance learning outcomes.	●○○○○	●●●●○	⇓
Community-Driven - Subjective evaluations	**Usage Statistics (Engagement metrics)**: Measures user engagement through tracking views, downloads, and time spent on content. This metric helps gauge the interest and relevance of content to its audience.	Implement analytics software that captures and reports detailed statistics on how users interact with the content. This includes tracking the number of views, downloads, and the average time users spend on each piece of content, which can indicate the content's engagement level and popularity.	●●●●○	●●●●○	⇑
	Ratings and Reviews (User evaluation): Collects user evaluations through ratings and reviews, providing insights into the content's perceived value and areas for improvement.	Enable a feature on the platform where users can rate content on a scale (e.g., 1 to 5 stars) and write reviews. Use NLP tools to perform thematic analysis of reviews to identify common praises or concerns, helping guide content updates and curation.	●●●○○	●●●●○	⇒
	Endorsements (User support): Tracks the number of endorsements each piece of content receives from users, which can serve as a quality signal and peer recommendation.	Incorporate a feature that allows users to endorse content they find particularly valuable. Track and analyze these endorsements to prioritize highly supported content in search results and recommendations.	●○○○○	●○○○○	⇓
	Peer Review (Expert validation): Involves a formal review process by subject matter experts before content is published, ensuring accuracy, depth, and relevance.	Establish a panel of experts in BIM and related fields who review and approve content submissions before they go live. This peer review process ensures that all content meets high standards of quality and relevance.	●○○○○	●●●●○	⇓
	Adaptability Feedback (Ease of use): Gathers feedback on how easily users can adapt the educational content to different teaching and learning contexts.	Distribute surveys or feedback forms that ask educators and students about their experiences adapting the content to their specific needs. Analyze feedback to make content more flexible and useful in various educational settings.	●○○○○	●●●○○	⇓
	Testimonials and Feedback (User experiences): Collects detailed user testimonials and feedback to understand the impact of the content on users' learning and application.	Create a forum or feedback section where users can share detailed accounts of their experiences with the platform's content. Review these testimonials to gather qualitative insights into the effectiveness of the content and areas for improvement.	●○○○○	●●●○○	⇓
	Practical Application Case Studies (Real-world usage): Encourages users to submit case studies or examples of successfully applying the educational content in real-world settings.	Develop a submission platform or section within the site where users can share their case studies detailing the application of learned skills in their projects. This can provide practical insights and showcase the real-world applicability of the content.	●○○○○	●○○○○	⇓

In these two categories, we have identified a number of criteria that could help us to qualitatively measure the quality of the content contributed by the stakeholders. These are shown in table 1 together with an assessment of the simplicity of implementation and automation, which can be prioritized.
To evaluate the platform's effectiveness and impact, we will employ a set of metrics focused on user engagement, content quality, and educational outcomes. Success will be measured by quantitative metrics such as user growth and interaction rates and by qualitative feedback from the community, assessing improvements in learning outcomes, professional development, and industry-academia collaboration.

5. Limitations, Future Prospects, and Concluding Insights

The conceptualization of this open BIM education platform aims to serve as a comprehensive resource for learning and collaboration, fostering an active community that contributes to the digital transformation of the construction industry. However, the platform also presents challenges, particularly regarding the technical complexities of implementing BIM and interoperability issues that could impede seamless communication and data exchange. The platform's development and maintenance require substantial resources, underscoring the need for additional partners and funding sources.
To address these challenges, we focus on enhanced collaboration between academia and industry alongside the integration of current standards and best practices. Our approach, initially involving four BIM professors and their students from four universities of applied sciences in Germany, aims to foster a community-driven initiative. By engaging with potential collaborators and securing additional resources, we aim to overcome the hurdles of resource demands.
This platform holds significant potential for democratizing digital education in planning, construction, and operations, providing equal opportunities regardless of location. It is poised to be a pathfinder for a more inclusive and efficient training framework that covers the entire lifecycle of construction projects. The platform's open and location-independent nature ensures equitable access to resources, particularly in German-speaking regions and beyond. We anticipate that this initiative will significantly reduce delays in the digital transformation of the construction industry, promoting early and interdisciplinary training in a cost-effective manner.

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